From the Midwestern Vascular Surgical Society

Endovascular recanalization of total occlusions of the mesenteric and celiac arteries

Mel J. Sharafuddin, MD,[a,b] Rachael M. Nicholson, MD,[a] Timothy F. Kresowik, MD,[a] Parth B. Amin, MD,[a] Jamal J. Hoballah, MD,[a] and **William J. Sharp, MD,[a]** *Iowa City, Iowa*

Objective: **To evaluate our experience with the endovascular treatment of total occlusions of the mesenteric and celiac arteries.**

Methods: **We performed a retrospective review of endovascular stenting of 27 nonembolic total occlusions of the superior mesenteric artery (SMA) and celiac artery (CA) between July 2004 and July 2011 (26 patients, 16 females; mean age, 62 ± 13 years). A variety of demographic, lesion-related and procedure-related variables were evaluated for potential impact of technical success and patency. The follow-up protocol included clinical assessment, and color and spectral Doppler evaluation of the stented vessel(s).**

Results: **The clinical presentation was chronic mesenteric ischemia in 12 patients, acute mesenteric vascular syndromes in 10 patients, foregut ischemia/ischemic pancreatitis in three patients, and prior to endovascular repair of aortic aneurysm in one patient. The treated vessel was SMA in 22 procedures, CA in three, and both SMA and CA in one. Technical success was achieved in 23 of the 27 attempted recanalizations (85%). Three patients who failed the attempt underwent open bypass, and another one underwent retrograde recanalization and stenting of the SMA. Procedure success was only significantly related to patient age <70 years or procedure performance after the year 2006. Notably, the presence of a stump, ostial plaque, extensive vascular calcification, recanalization route (intraluminal vs subintimal), occlusion length, and vessel diameter had no significant impact on procedure success. Traditional duplex criteria proved unreliable in predicting restenosis. Life table analysis of freedom from symptom recurrence showed a primary and assisted rates of 58% and 80% at 1 year, and 33% and 60% at 2 years, respectively. Clinical recurrences developed in six patients (four presented with abdominal angina and weight loss, two presented with abdominal catastrophe). There were six access-related complications and no procedural deaths. Four delayed deaths occurred during follow-up (two cardiac causes, two due to abdominal sepsis).**

Conclusions: **Endovascular recanalization of mesenteric artery occlusion is both feasible and successful, provided careful planning is used. (J Vasc Surg 2012;55:1674-81.)**

While asymptomatic mesenteric vascular occlusive disease (MVOD) occurs commonly in patients with established vascular risk factors,[1] progression to symptomatic mesenteric ischemia can develop, especially in patient with two- and three-vessel disease. Endovascular treatment in symptomatic mesenteric occlusive disease represents a viable option, especially in high-operative-risk patients.[2] However, the role of endovascular treatment in patients presenting with acute mesenteric syndromes (acute or acute-on-chronic mesenteric ischemia) is controversial. The presence of total occlusions represents a major obstacle to successful endovascular treatment of MVOD.[3-5] Total occlusions are commonly encountered in symptomatic MVOD patients, especially patients presenting with the acute syndromes. Despite the growing experience and skills in the endovascular management of MVOD, total occlusion of the mesenteric vessels continues to be controversial, and is even considered an indication for open surgery in the setting of symptomatic MVOD.[3] However, open mesenteric revascularization procedures, including bypass or endarterectomy, carry a substantial mortality and morbidity risks, especially in the typically malnourished patients, with extensive cardiovascular risk factors.[6]

The purpose of this study is to evaluate our experience with the endovascular treatment of total occlusions of the mesenteric and celiac arteries.

METHODS

We conducted a retrospective review of our departmental experience with endovascular stenting of the superior mesenteric artery (SMA) and celiac artery (CA) between July 2004 and July 2011. Only patients who underwent attempted recanalization of a total occlusion of either SMA or CA were included in the study. Embolic occlusions were excluded. During the study period, a total of eight patients underwent an open mesenteric bypass procedure, excluding those done in conjunction with aneurysm repair. This figure includes three patients who underwent open bypass following failed endovascular recanalization. The study population consisted of a total of 27 nonembolic total occlusions that were targeted endovascularly with the in-

From the Departments of Surgery[a] and Radiology,[b] The University of Iowa Roy and Lucille Carver College of Medicine.

Author conflict of interest: none.

Presented in part at the Thirty-fifth Annual Meeting of the Midwestern Vascular Surgical Society, Chicago, Ill, September 15-17, 2011.

Reprint requests: Mel J. Sharafuddin, MD, University of Iowa HealthCare, Department of Surgery, 200 Hawkins Dr., Iowa City, IA 52242 (e-mail: mel-sharafuddin@uiowa.edu).

The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214/$36.00

doi:10.1016/j.jvs.2011.12.013

Table I. Summary of clinical presentation and vascular risk factors

Indication for intervention	*No.*
Chronic mesenteric ischemia	12
Acute mesenteric ischemia or acute-on-chronic mesenteric ischemia	10
Foregut ischemia, ischemic pancreatitis/hepatitis	3
Prior to endovascular aneurysm repair[a]	1
Vascular risk factors	*No.*
Tobacco abuse	23
Hyperlipidemia	21
Hypertension	16
Diabetes mellitus	4
Hypercoagulable state	2
Chronic renal failure	1

[a]Celiac artery and superior mesenteric artery occlusion.

tent to treat in 26 patients. There were 16 females and 10 males (mean age, 62 ± 13 years). The clinical characteristics of the study population are listed in Table I. The clinical presentation was chronic mesenteric ischemia (CMI) in 12 patients, manifesting in postprandial abdominal angina and weight loss. Acute mesenteric ischemia (AMI) was defined by the presence of any combination of persistent abdominal pain, mild peritoneal signs, leukocytosis, and lactic acidosis. Imaging findings were also used to rule out AMI, especially computerized tomography (CT). Acute-on-chronic mesenteric ischemia (AOCMI) referred to an acute presentation with a prior history of abdominal angina or weight loss ≥10 pounds. Another group of patients with an acute presentation were those who had a presentation related to foregut ischemia (postprandial pain, nausea with ischemic ulcers of the stomach and duodenum), suspected ischemic pancreatitis, or suspected ischemic hepatitis. However, these patients were considered separate from those presenting with AMI syndromes (AMI or AOCMI). One patient underwent SMA recanalization prior to endovascular aneurysm repair to lower the risk of mesenteric ischemia following exclusion of the inferior mesenteric artery. Outcomes were evaluated on an intent-to-treat basis. Any patient who underwent an unsuccessful attempt at endovascular recanalization with subsequent open revascularization was considered a procedural failure.

Presentation with an AMI syndrome (AMI or AOCMI) was identified in 10 patients (38%). Of those, four patients first underwent exploratory laparotomy to assess bowel viability and/or manage intra-abdominal complications such as bowel gangrene, enterocutaneous fistula, or abdominal abscess. Two of these patients underwent a revascularization attempt during the laparotomy procedure. In one patient, we attempted open revascularization, which was aborted due to an extremely hostile abdomen, in favor of an endovascular revascularization attempt. Another patient had an unsuccessful percutaneous recanalization attempt of an occluded SMA, and a hybrid retrograde recanalization approach was used, allowing successful stenting of the SMA. That patient was considered a procedure failure. The remaining two patients underwent segmental resection of necrotic bowel and/or repair of enteric fistulae, with the remaining bowel appearing viable. Subsequent endovascular revascularization was performed in both in a formal angiography suite. In one additional patient, vascular consultation was requested 48 hours after the onset of symptoms, following failed endovascular recanalization by another service. The general surgery service was consulted, and we proceeded with endovascular recanalization, followed by an intraperitoneal bowel exploratory procedure.

Preprocedural CT scans were carefully examined for associated thrombus in the reconstituted vessel. Thrombus was suspected based on CT in two patients. In one, pulse-spray thrombolysis was performed following which stenting was accomplished. In the other patient, we used an iCAST balloon-expanded stent graft (Atrium Medical, Hudson, NH) without thrombolysis. Thrombus burden was felt to be small in both patients, and postdeployment angiography showed no evidence of major embolism. All procedures were performed under therapeutic systemic heparinization. Following the intervention, all patients were maintained on either therapeutic warfarin (n = 5) or clopidogrel 75 mg orally daily in addition to aspirin 81 to 325 mg orally daily (n = 21).

Successful recanalization appeared to be most dependent on the identification of an appropriate probing point to initiate the recanalization sequence and a stable catheter position. In our experience, this often necessitated a brachial approach. Coaxial support using a flexible sheath was crucial in transfemoral procedures. Once a stable platform was achieved, the stump is probed with an appropriate catheter/glide wire combination. The most useful combinations were multipurpose angiographic catheter/angled glide wire from a brachial approach, or Simmons-1 or -2 catheter/angled glide wire from a transfemoral approach. In patients with flush occlusions and no visible stump, which we termed "obliterated stump," we have found that correlation with preoperative cross-sectional imaging (usually CT) is critical for the localization of the obliterated stump, usually in reference to a radio-opaque landmark or an adjacent patent vessel such as the renal artery (Fig 1). Alternatively, in the presence of heavy vascular calcifications, the location of the stump can be estimated according to the calcification pattern. Good fluoroscopic capability in the lateral projection is crucial during those attempts, and a brachial approach is nearly always needed. Through a stable support sheath or guide catheter platform, angled angiographic catheters with a guide wire are used coaxially to probe the obliterated stump. Occasionally, traversal of the occlusion is accomplished easily, but at times, it may require an incremental advancement (burrowing) approach (Fig 2). Once intraluminal reentry is achieved, the position is verified with contrast injection, the occlusion is predilated, and stenting is accomplished in a standard manner.

Fig 1. Example of recanalization of occluded superior mesenteric artery (SMA) in the setting of an obliterated stump in a 47-year-old woman who presented with an acute abdomen. During exploratory laparotomy, she was found to have an intra-abdominal abscess with extensive inflammation, segmental of patchy ischemia of the small bowel, and a pulseless mesentery. Revascularization was deemed difficult given the hostile abdomen. **A,** Lateral reconstruction of a contrast-enhanced computerized tomography (CT) of the abdomen shows occlusion of the celiac artery (CA) and SMA with no visible stumps. **B,** Axial slice demonstrates an obliterated stump of the SMA, which is just above the takeoff of the renal arteries. **C,** Lateral flush aortogram from a brachial approach demonstrates a featureless suprarenal aorta with no stumps visualized. **D,** Probing anteriorly at the level of the renal artery engaged the obliterated stump of the SMA, with subsequent subintimal recanalization. **E,** Final angiography following deployment of a 5- × 28-mm balloon-expanded stent.

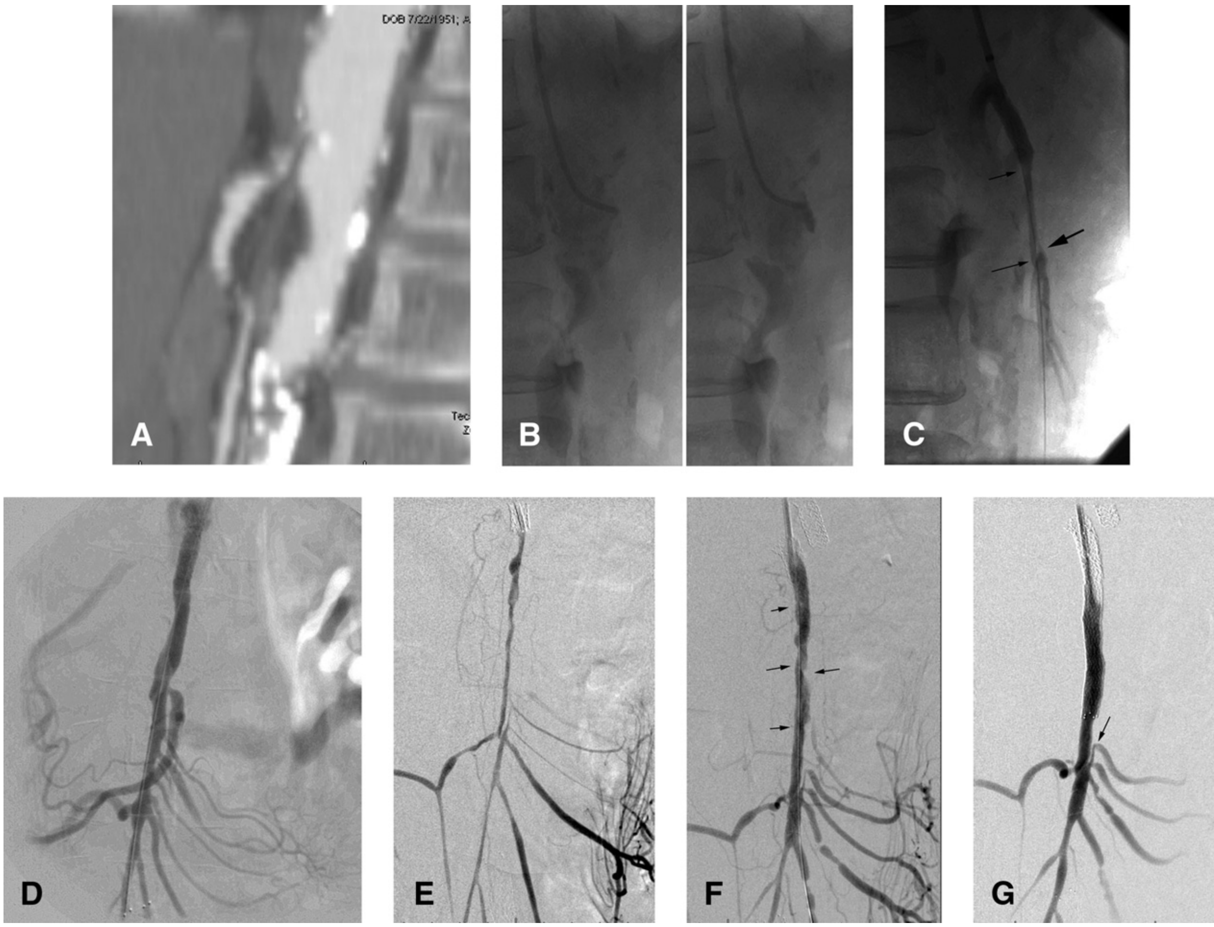

Fig 2. Sixty-year-old woman with extensive peripheral vascular disease presenting with severe postprandial pain, fear of eating, and 20-pound weight loss. **A,** Lateral reconstruction of a contrast-enhanced computerized tomography (CT) of the abdomen shows a 3-cm-long occlusion of the superior mesenteric artery (SMA) with no visible stump. **B,** Progressive burrowing at the suspected level of the obliterated SMAP stump, using the celiac artery and visible calcifications on fluoroscopy as a reference. **C,** Ostial stenting of the SMA with balloon dilatation of the recanalized track shows recoil of the subintimal track. **D,** Final appearance following prolonged inflation of 5-mm balloon diameter shows an optimal anatomic result. **E,** Angiography showed in-stent restenosis and restenosis/recoil of the subintimal-true lumen fenestration. **F,** Following scoring balloon angioplasty, there is improved flow but hazy appearance of the mid-SMA. **G,** Final result following placement of a 6- × 100-mm self-expanding nitinol stent.

A variety of variables were evaluated for potential impact of technical success and patency. These included: procedures performed before the year 2006, age, gender, presentation (acute, acute mesenteric syndrome, chronic), vascular risk factors, vessel treated, presence of a stump, heavy calcification, associated ostial plaque, length of the occluded segment, diameter of the reconstituted index vessel, access approach, recanalization technique (intraluminal vs subintimal), stent diameter, length of stented segment, and angiographic residual stenosis following stenting.

The follow-up protocol included clinical assessment, and color and spectral Doppler evaluation of the stented vessel on the follow-up visits, usually at 1 month, 3 months, 6 months, and 12 months, and yearly thereafter. Restenosis on follow-up was defined by angiographic or duplex documentation of stenosis ≥70% (peak systolic velocity [PSV] >300 cm/s). However, due to the high rate of elevated velocities (>300 cm/s) observed immediately following stenting in our experience, we adopted more lenient criteria for assignment of restenosis in stented mesenteric vessels (PSV >400 cm/s). Moreover, we examined the sensitivity and specificity of duplex sonography in 23 patients who had both duplex and clinical follow-up available. Using the PSV >300 cm/s criterion, there were eight false positives, four true positives, and one false negative. When the PSV >400 cm/s criterion was used, there were only two false positives, while the true positives and false negative remained at four and one. Symptoms recurrence or development of progressive increase in velocities on duplex usually prompted cross-

Table II. Patterns of anatomic disease and intervention

Disease distribution	
Three vessels	6
Two vessels	15
One vessel (SMA)	5
Targeted (index) occluded vessel	
SMA	22
CA	3
SMA + CA	1
Additional stenotic vessels treated	
SMA	3
CA	5
IMA	1

CA, Celiac artery; *IMA*, inferior mesenteric artery; *SMA*, superior mesenteric artery.

sectional imaging with CT angiography. When high-grade preocclusive or rapidly progressive stenosis was identified or when clinical recurrence of symptoms was suspected and associated restenosis was confirmed, we proceeded with mesenteric angiography with the intent to treat any amenable lesions. Primary clinical benefit was defined as freedom from symptoms recurrence on the follow-up point. Primary patency of the treated segment was also evaluated as "freedom from restenosis," as assessed by composite evaluation using PSV >400 cm/s on spectral Doppler analysis and/or lumen diameter stenosis ≥70% on CT angiography. Assisted primary clinical benefit and primary patency were also assessed, and refer to restoration and maintenance of freedom from symptoms or patency by endovascular means, using repeat balloon dilatation and/or restenting. Thromboses and recurrences that could not be treated by endovascular means were considered as a patency loss. Statistical comparison of the various variables was performed using SYSTAT 11.0 software (SPSS, Inc., Chicago, Ill). Univariate analysis of continuous numeric variables was done using the Student *t*-test, while the Pearson χ^2 probability test was used for comparing non-numeric categorical variables. Survival analysis was generated using GraphPad Prism version 5.04 for Windows (GraphPad Software, San Diego, Calif).

RESULTS

The anatomic patterns of disease and technical details of the interventions are summarized in Tables II and III. Although in most procedures, only one stent was used, two to three stents were required in four procedures. A variety of balloon-expanded stents were used, including: Express (Boston Scientific, Natick, Mass), Formula (Cook, Bloomington, Ind), and Omnilink or Herculink (Abbott, Abbott Park, Ill).

Using an intent-to-treat analysis, technical success was achieved in 23 of the 27 recanalization attempts (85%). All four failures were in SMA occlusions. Three patients who failed the recanalization attempt underwent an open bypass procedure. The fourth patient labeled as a technical failure presented with acute mesenteric syndrome and failed an attempt at endovascular recanalization during initial exploratory laparotomy. She underwent retrograde recanalization and stenting of the SMA in the same setting in the hybrid operating suite. Interestingly, balloon thrombectomy through the SMA arteriotomy yielded no thrombus. Evaluation of a variety of patient-related, lesion-related, and procedure-related variables showed that procedure success was only significantly related to patient age <70 years or procedure performance after the year 2006. Notably, the presence of a stump, ostial plaque, extensive vascular calcification, recanalization route (intraluminal vs subintimal), occlusion length, and vessel diameter had no significant impact on procedure success.

Table III. Technical details of 27 recanalization procedures

Technical success	23/27 (85%)
Lesion characteristics	
Index vessel diameter	5.5 ± 0.6 mm
Type of stenosis	
De novo	25
In-stent restenosis	1
Dissection	1
Length	18.5 ± 6.5 mm
Associated thrombus	2[a]
Heavy calcification	16
Ostial plaque	13
Stump (>2 mm)	14
Occlusion recanalization technique	
Brachial approach	16
Femoral converted to brachial approach	7
Subintimal	9
Intraluminal	17
Stenting details	
More than one stent needed	4/23
Stent graft	1
Final stent diameter	5.8 ± 0.6 mm
Stented length	22.3 ± 8.2 mm
Residual stenosis	14.1 ± 15.5 mm
Adjunct thrombolysis	1

[a]Small.

Procedure-related complications included five instances of brachial artery thrombosis/hematoma necessitating exploration with thrombectomy and/or repair. One groin hematoma with a femoral pseudoaneurysm was observed in one patient. Mild azotemia occurred in two patients and resolved spontaneously. There were no procedure-related deaths.

Clinical improvement was noted in 20 of 21 symptomatic patients in whom endovascular recanalization was successful. The one exception was a patient who had atypical abdominal symptoms and weight loss. He eventually had an additional gastroenterological workup, and his symptoms and weight loss stabilized on dietary modifications. Another patient was asymptomatic preoperatively but underwent SMA recanalization prior to an endovascular abdominal aortic aneurysm repair procedure. Of note is that all three patients with foregut and pancreaticohepatic symptomatology improved with stenting. Clinical and imaging follow-up results are summarized in Table IV. The median clinical follow-up was 14 ± 11 months (range, 0-41 months). The median imaging follow-up was 11 ± 10

Table IV. Summary of the hemodynamic and clinical outcomes of interventions

Duplex findings	*Immediate poststenting*	*On follow-up*	P
PSV (cm/s)	247 ± 117	313 ± 116	.1
PSV ≥300 cm/s	6/23	12/25	.06
PSV ≥400 cm/s	1/23	4/25	.15
Clinical recurrences[a]		*n* = 6	
Median delay		10 ± 2.7 months[b]	
Recurrent abdominal angina/weight loss		4	
Abdominal catastrophe		2	
Deaths			
Median delay		22 ± 16 months[c]	
Cardiac events		2[d]	
Abdominal catastrophe/sepsis		2[e]	

PSV, Peak systolic velocity.
Median clinical follow-up: 14 ± 11 months (range, 0-41 months). Median imaging follow-up (11 ± 10 months (range, 1-41 months).
[a]All associated with restenosis/reocclusion on imaging.
[b]Range, 5-11 months.
[c]Range, 2-43 months.
[d]At 19 and 43 months.
[e]At 2 and 23 months.

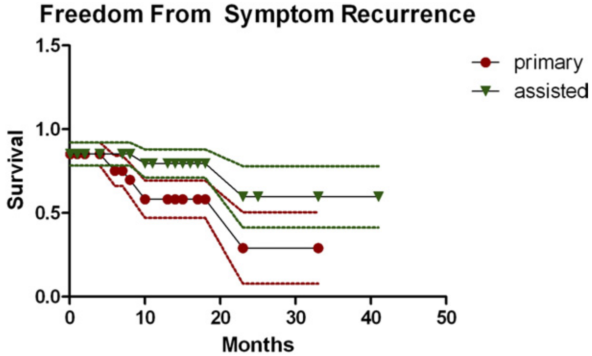

Fig 3. Table analysis of primary and assisted freedom from symptoms. Comparison of the primary and assisted curves using log-rank Cox analysis showed significant difference ($P = .05$).

months (range, 1-41 months). Life table analysis of freedom from symptom recurrence was analyzed (Fig 3). Primary clinical patency diminished to 58% at 1 year and 33% at 2 years. Assisted clinical patency at 12 months was 80% decreasing to 60% at 2 years. Log-rank Cox test showed significant difference between the two curves ($P = .05$).

Clinical recurrences developed in six patients and were all associated with documented restenosis on imaging studies. Four of the recurrences presented with abdominal angina and weight loss. All underwent angiography documenting high-grade in-stent restenosis, which were successfully treated with balloon angioplasty and/or restenting. This includes one patient who had undergone subintimal recanalization of a long occlusion with partial false lumen reentry. She developed restenosis 1 month later, which required balloon angioplasty followed by long-segment stenting to manage resistant lumen recoil. She fared well afterwards and remains symptom-free with non-stenosed duplex examination nearly 11 months later (Fig 2).

Two additional clinical recurrences presented acutely with abdominal catastrophe. Both occurred in young patients with hypercoagulability history and either subtherapeutic anticoagulation or discontinuation of anticoagulation therapy. In both, reocclusion of an SMA stent had occurred, with the CA also being chronically occluded. The first patient had undergone recanalization and stenting of the SMA, followed by second-look surgery with resection of approximately 3 feet of small intestines. He did well initially but later was lost to follow-up. He presented 10 months following the stenting procedure with intra-abdominal sepsis due to extensive bowel necrosis. Repeat imaging showed development of thrombosis in the SMA in the segment beyond the occluded stent, which probably accounted for his extensive ischemia. Attempted recanalization of the stent was unsuccessful, and the patient declined an open bypass procedure. He eventually required subtotal bowel resection and is now parenteral nutrition-dependent. The second patient initially presented with bowel necrosis, necessitating emergent exploration and resection of gangrenous small intestine. Intraoperative vascular consultation determined that the abdomen was too hostile for a bypass, and the patient underwent recanalization of an occluded SMA. She did well for nearly 2 years with documented patency on duplex sonography. However, her anticoagulation regimen was completely discontinued for an abdominal hernia repair procedure. She presented 1 week later with abdominal sepsis and was found to have extensive bowel necrosis and sepsis. She eventually succumbed to multiorgan system failure.

Nominal stent diameter ≤5 mm and residual stenosis ≥40% following stenting were both predictive of clinical recurrence as well as restenosis on imaging ($P = .07$ and $P = .05$, respectively). The remaining studied variables had no statistical impact, including age, gender, recanalization route, lesion morphology, and length of occlusion.

Four deaths occurred during the follow-up at a mean 22 ± 16 months after the procedure. Two deaths were due to cardiac events (19 and 43 months). Two additional deaths due to abdominal catastrophe and sepsis occurred at 2 and 23 months following the procedure.

DISCUSSION

Total occlusions in the mesenteric circulation pose a particularly difficult challenge, due to the often steep orientation of these vessels, and anterior origin from the aorta, which necessitates a lateral/sagittal plane imaging for adequate profiling. In our experience with 27 SMA and CA total occlusions, nearly half had no angiographically visible stump, which we term "obliterated stump." Antegrade recanalization in those cases would normally be considered nearly impossible. We therefore relied on a number of strategies, which in our experience, resulted in a high rate of success. This includes the use of lateral fluoroscopy to identify vascular calcifications that could mark the origin of the SMA or CA, essentially serving as a fluoroscopic marker of an otherwise occult stump. Otherwise, preoperative contrast-enhanced CT has proven very useful in marking the level and orientation of an obliterated stump, relative to an adjacent patent vessel to be used as reference point for exploratory probing of the obliterated stump.

Our study represents the largest reported series on the endovascular management of totally occluded mesenteric and celiac arteries. One recent study by Sarac et al reported on 18 totally occluded mesenteric vessels and compared the outcome and patency with 47 stenotic lesions.[4] It concluded that the results of endovascular treatment of totally occluded mesenteric arteries are indistinguishable from those in stenotic vessels. However, our results, when compared with our prior published experience in a population of mostly stenotic lesions,[7] would suggest a lower primary patency rate with total occlusions, although the retrospective nature and the time lag between the two studies may introduce confounding factors that could have contributed to the discrepant outcomes. Nevertheless, the observed difference may well be the results of different study designs. Although not specifically stated in the article, examination of the report by Sarac et al suggests that patency rates were compared between lesions that were successfully treated, whereas our data were analyzed on an intent-to-treat basis, which could explain our lower primary patency rates. Moreover, a much higher proportion of the occlusions in our study were in patients presenting with acute mesenteric syndromes (40% compared with only 3%). This could have a negative impact on patency because of the possibility of an unrecognized associated thrombotic component in the occlusions or possibly unfavorable biological response to stenting.

We have observed potentially serious drawbacks of subintimal recanalization in severely diseased and calcified vessels where reentry into the true lumen occurred beyond the point of reconstitution. This may have serious consequences such as accelerated restenosis and clinical recurrence, which we observed in the patient described above, who developed symptomatic restenosis less than a month after the procedure. She underwent reintervention and eventually required stenting of a long segment of the proximal through mid-SMA to maintain patency (Fig 2).

The importance of multivessel revascularization has been repeatedly stressed in the surgical literature as a major advantage to open revascularization.[3] A particularly "at-risk" group of patients with MOVD include those with total occlusion of both the SMA and CA who undergo "single-vessel" endovascular revascularization. Such patients are at high risk of developing a catastrophic event if the stented vessel becomes occluded. As a result, in patients with occluded SMA and severe disease of the celiac, our approach should likely shift to attempting stenting of a second diseased or occluded vessel to effectively achieve dual mesenteric revascularization. Even subsequent elective surgical revascularization once the patient is stable enough may be a consideration.

Reported mortality related to acute mesenteric arterial occlusion remains high.[8] Although endovascular therapy in AMI remains controversial, mounting literature suggests an important role that could be played by these emerging technologies.[5,9] In fact, recent pooled analysis of revascularization procedures performed for AMI in Sweden shows a current predominance of endovascular techniques, which is a complete trend reversal since 2004.[10] Our study confirms the feasibility of revascularization in patients presenting with acute mesenteric ischemic syndrome. However, it should be stressed that patients in our study who presented with the acute mesenteric syndromes either presented with clinically milder variants ($n = 7$) or had open abdominal exploration as a component of the management either in conjunction with endovascular recanalization. Needless to say, successful endovascular recanalization of vascular occlusions in this setting should not replace the need for careful assessment of bowel viability. While in patients with mild physical and laboratory findings, a conservative approach with careful follow-up may be applicable, there should be no hesitation about implementing a routine second-look strategy (open or laparoscopic) to avert the potential disastrous consequences of missed gangrenous bowel transformation.

An interesting observation in our series is the relative paucity of thrombus burden despite the high clinical prevalence of acute mesenteric ischemic syndrome (38%). Only two lesions (20%) were suspected of having a thrombotic component based on CT angiography. Catheter angiography demonstrated a small thrombus burden in both, which was treated with pulse-spray thrombolysis in one and primary stent graft placement in the other. No angiographically significant embolic events were detected, but the potential for microembolization, which may have serious detrimental consequences on bowel viability in these compromised patients, cannot be excluded. Associated occult thrombus in these chronic occlusions may also have an adverse effect on long-term patency. An argument may thus be made for routine administration of a thrombolytic agent prior to stenting. Angiographically visible thrombosis may be rapidly managed with a brief course of pulse-spray thrombolysis, aspiration thrombectomy, or mechanical thrombectomy using a flexible over-the-wire device.[11,12] The use of primary stent graft deployment may also provide a viable option in patients where acute revascularization is desired. Stenting of the SMA has been proposed by some as an alternative in treating thrombotic occlusion. Balloon-expandable stents are used to treat stiff ostial lesions, and self-expanding stents are then used as distal extensions, achieving a smoother transition to the native SMA.[5]

Another important observation is the reduced patency and high clinical recurrence rates in smaller vessels necessitating a stent 5 mm or smaller in nominal diameter. This trend has been previously observed in renal artery stenting.[13] An argument can therefore be made for the use of drug-eluting stents in small mesenteric vessels, a strategy also proven of potential value in small renal arteries.[13]

Our study also suggested a high rate of access-related complications, predominantly related to the frequent use of brachial access. These included hematomas, pseudoaneurysms, and thrombosis. A point can be made about the importance of access under ultrasound guidance at the level of the antecubital fossa, and not waiting for normalization of the activated clotting time before sheath withdrawal. In patients with small disease brachial arteries, access via a cut down may be prudent.

Our study also brings up the deficiency of the current native mesenteric vessels criteria for stenosis. The currently used duplex criterion for significant SMA stenosis (>70%) is PSV >275 cm/s.[14] We have found even a more lenient duplex criterion (PSV >300 cm/s) to correlate poorly with clinical symptom recurrence. A threshold of PSV >400 cm/s correlated better with clinical recurrences. These drawbacks of duplex evaluation of the stented SMA have been previously described.[15] Other problems with duplex include its operator-dependent nature, frequent poor visualization in nonfasting patients due to overlying bowel gas, and its known dependence on prandial status. Our approach has been to obtain a baseline study immediately following a technically successful stenting procedure. We have a higher arbitrary threshold (400 cm/s) that we use as screening tool, and place a greater emphasis on short-term serial follow-up studies. Progressive elevated velocities >400 cm/s or high clinical suspicion of recurrence should trigger further evaluations using computed tomography angiography or catheter angiography.

In conclusion, our experience in this challenging group of patients supports the feasibility and short-term clinical efficacy of endovascular recanalization of total occlusions of the superior mesenteric and celiac arteries, provided careful planning is used. CT and good-quality fixed lateral fluoroscopy were crucial for the localization of the stump and to plan the level of probing on angiography during the recanalization procedure, even when a stump was not visualized on angiography.

AUTHOR CONTRIBUTIONS

Conception and design: MS, RN, TK
Analysis and interpretation: MS, RN, PA, TK
Data collection: MS, RN, TK, PA, TK, WS, JH
Writing the article: MS
Critical revision of the article: RN, TK, WS, JH
Final approval of the article: MS
Statistical analysis: MS
Obtained funding: MS
Overall responsibility: MS

REFERENCES

1. Thomas JH, Blake K, Pierce GE, Hermreck AS, Seigel E. The clinical course of asymptomatic mesenteric arterial stenosis. J Vasc Surg 1998; 27:840-4.
2. Fioole B, van de Rest HJ, Meijer JR, van Leersum M, van Koeverden S, Moll FL, et al. Percutaneous transluminal angioplasty and stenting as first-choice treatment in patients with chronic mesenteric ischemia. J Vasc Surg 2010;51:386-91.
3. Oderich GS, Gloviczki P, Bower TC. Open surgical treatment for chronic mesenteric ischemia in the endovascular era: when it is necessary and what is the preferred technique? Semin Vasc Surg 2010;23:36-46.
4. Sarac TP, Altinel O, Kashyap V, Bena J, Lyden S, Sruvastava S, et al. Endovascular treatment of stenotic and occluded visceral arteries for chronic mesenteric ischemia. J Vasc Surg 2008;47:485-91.
5. Resch TA, Acosta S, Sonesson B. Endovascular techniques in acute arterial mesenteric ischemia. Semin Vasc Surg 2010;23:29-35.
6. Mateo RB, O'Hara PJ, Hertzer NR, Mascha EJ, Beven EG, Krajewski LP. Elective surgical treatment of symptomatic chronic mesenteric occlusive disease: early results and late outcomes. J Vasc Surg 1999;29: 821-32.
7. Sharafuddin MJ, Olson CH, Sun S, Kresowik TF, Corson JD. Endovascular treatment of celiac and mesenteric arteries stenoses: applications and results. J Vasc Surg 2003;38:692-8.
8. Wyers MC. Acute mesenteric ischemia: diagnostic approach and surgical treatment. Semin Vasc Surg 2010;23:9-20.
9. Block TA, Acosta S, Björck M. Endovascular and open surgery for acute occlusion of the superior mesenteric artery. J Vasc Surg 2010; 52:959-66.
10. Block T. Acute occlusion of the superior mesenteric artery. Diagnosis and treatment. Uppsala: Acta Universitatis Upsaliensis; 2010.
11. Popovič P, Kuhelj D, Bunc M. Superior mesenteric artery embolism treated with percutaneous mechanical thrombectomy. Cardiovasc Interv Radiol 2011;34:67-9.
12. Nishida A, Fukui K. Images in clinical medicine. Transcatheter treatment of thromboembolism in the superior mesenteric artery. N Engl J Med 2005;353:e4.
13. Zeller T, Rastan A, Rothenpieler U, Müller C. Restenosis after stenting of atherosclerotic renal artery stenosis: is there a rationale for the use of drug-eluting stents? Catheter Cardiovasc Interventions 2006;68:125-30.
14. Zwolak RM, Fillinger MF, Walsh DB, LaBombard FE, Musson A, Darling CE, et al. Mesenteric and celiac duplex scanning: a validation study. J Vasc Surg Jun 1998;27:1078-87; Discussion:1088.
15. Mitchell EL, Chang EY, Landry GJ, Liem TK, Keller FS, Moneta GL. Duplex criteria for native superior mesenteric artery stenosis overestimate stenosis in stented superior mesenteric arteries. J Vasc Surg 2009;50:335-40.

Submitted Sep 20, 2011; accepted Dec 8, 2011.